25X1A

Some installation requirements may necessitate inversion of the standard mounting brackets, which will increase the clearance where necessary.

The weld-nuts on tank are spaced so as to accept EEI-NEMA bracket.

LIGHTNING ARRESTER CLEARANCES

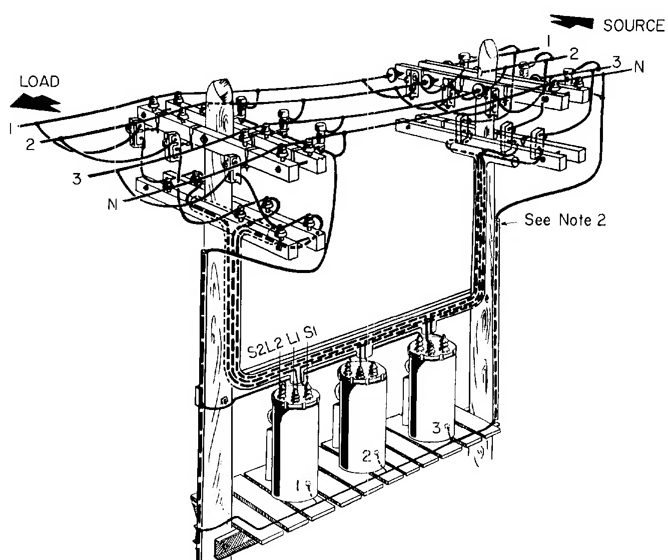
REGULATOR VOLTAGE CLASS (KV-RMS)	MINIMUM SUGGESTED CLEARANCE (INCHES)
2.5	4
5.0	5
7.62	6
13.8	6
14.4	9½
20	9½

If the arresters are not mounted on the regulator, they should be installed within 10 feet of the regulator and the ground of the arrester should be connected directly to the ground lug of the regulator tank.

SHORT-CIRCUIT RATING

The impedance of a regulator is practically negligible for reducing short-circuit current. The impedance of the feeder up to the point at which the regulator is installed should be sufficient to limit the short-circuit current in the regulator to the value for which it is designed. It is recommended that feeder current-limiting reactors be installed on the feeder to keep the short-circuit current within the required limits.

Short-circuit rating on any position is 40 times the rated current at ±10 percent regulation for 0.8 seconds. For short-circuit duration above 0.8 seconds the permissible short-circuit current is reduced to keep the product I^2t constant. In this formula I is the short-circuit current and t is the time in seconds. For instance, if the regulator is rated 2500 volts, 400 amperes, at ±10 percent regulation, $I^2t = (400 \times 40)^2 \times 0.8 = 205 \times 10^6$. Then for a short-circuit duration of 2 seconds, $2I^2 = 205 \times 10^6$ and $I = 10{,}100$ amperes.



NOTES:

1. The three by-pass cutouts are mounted on the side of the crossarm toward the installation for clarity of illustration. Mount these by-pass cutouts on the opposite side of the crossarm with the same line connections as shown.
2. Tie lightning arrester grounds together and connect to tank ground lug.

Typical three-phase installation

CONNECTION DIAGRAMS

WHEN REGULATOR IS IN NEUTRAL POSITION OR WHEN REGULATOR CAN BE RUN TO NEUTRAL POSITION

If there is any doubt that the regulator is on the neutral position, follow the instructions below, or check the position of the reversing switch by removing the handhole cover. When the regluator is in the neutral position the movable contact of the reversing switch is in a vertical position. CAUTION: Make this inspection only when the regulator is de-energized.

WARNING: Do not use any automatic circuit-opening elements between the line and SL bushing, such as: fuses, cutouts or circuit breakers. This connection should never be opened unless the regulator is in the neutral position. When the connection to the SL bushing is open, the regulator acts as a current transformer with open-circuited secondary. Dangerous voltages are induced in the series and exciting windings if any load current flows in the series winding.

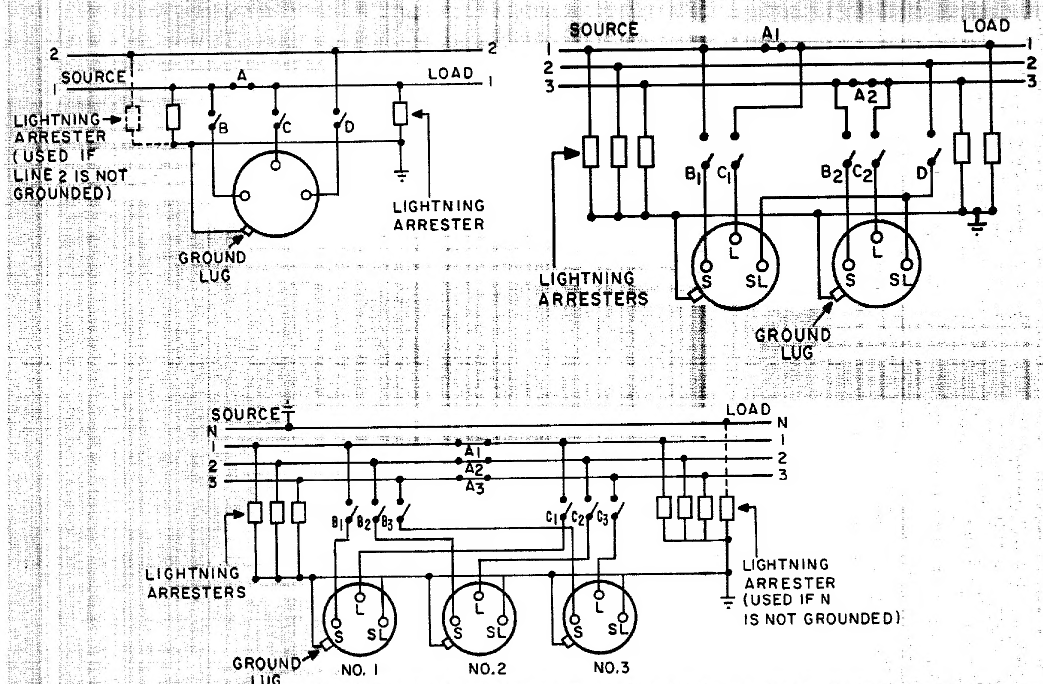
CONNECTING INTO SERVICE:

1. *Open the control circuit.*
2. *Close device B (and D if used).*
3. *Close the control circuit and run the regulator to neutral by manual control; then reopen the control circuit.*
4. *Close device C.*
5. *Open device A.*
6. *Close control circuit and place control on AUTO.*

REMOVING FROM SERVICE:

1. *Set the regulator on neutral by manual control, then open the control circuit.*
2. *Close line at A.*
3. *Open B and C (and D if used).*

CAUTION: TO AVOID BURNOUT OF WINDINGS, DEVICE "A" MUST NEVER BE CLOSED WITH THE REGULATOR CONNECTED TO THE LINE EXCEPT WHEN IN THE NEUTRAL POSITION.



A, B, C (and D if used) are disconnects suitable for line current.

Fig. 3. Connecting regulator in and removing from service without interrupting load

CONNECTION DIAGRAMS (CONT'D)

	CONNECTIONS			
VOLTS PERCENT	POSITION NUMBER	SWITCH M TO	CONNECTS A TO	B TO
10	16	Q	C	C
9 3/8	15		D	C
8 3/4	14		D	D
8 1/8	13		E	D
7 1/2	12		E	E
6 7/8	11		F	E
RAISE 6 1/4	10		F	F
5 5/8	9		G	F
5	8		G	G
4 3/8	7		H	G
3 3/4	6		H	H
3 1/8	5		K	H
2 1/2	4		K	K
1 7/8	3		L	K
1 1/4	2		L	L
5/8	1		M	L
NEUTRAL	0	OPEN	M	M
5/8	1	P	C	M
1 1/4	2		C	C
1 7/8	3		D	C
2 1/2	4		D	D
3 1/8	5		E	D
3 3/4	6		E	E
4 3/8	7		F	E
LOWER 5	8		F	F
5 5/8	9		G	F
6 1/4	10		G	G
6 7/8	11		H	G
7 1/2	12		H	H
8 1/8	13		K	H
8 3/4	14		K	K
9 3/8	15		L	K
10	16		L	L

Fig. 4. Switching mechanism connections

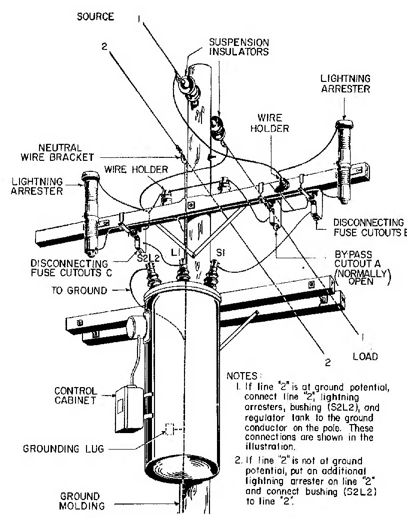


Fig. 5. Typical single-phase installation

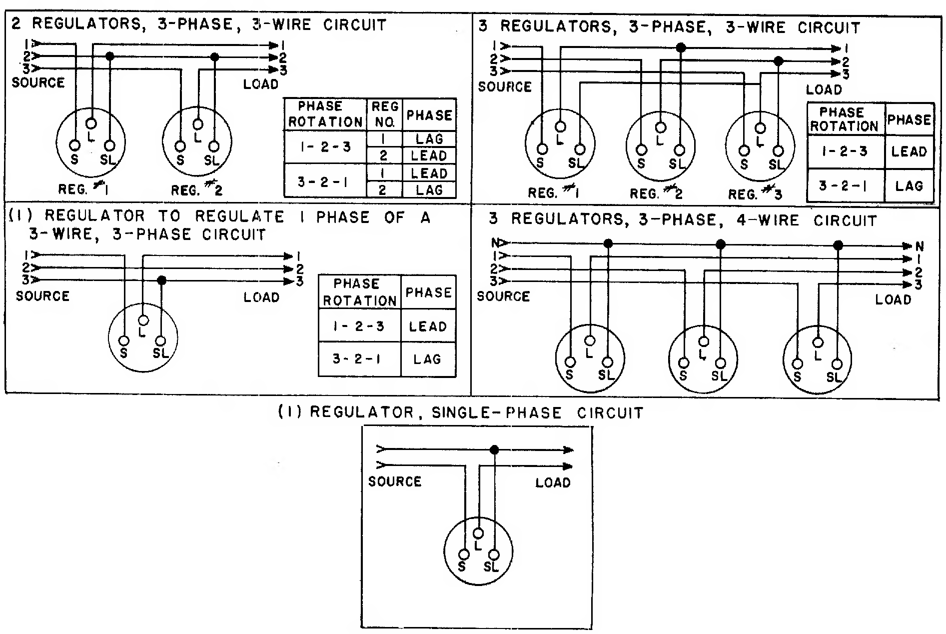


Fig. 6. Feeder connections

OPERATION

LOAD-BONUS OPERATION

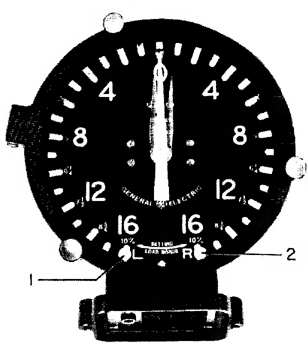
The load-bonus feature provides a means of operating the regulator at increased load by decreasing the range of regulation in 1¼ percent steps. Load current may be increased up to 160 percent of rated current when operated at ±5 percent regulation (with a limit of 668 amperes). Refer to nameplate for rating at load-bonus settings.

To make adjustments, set the limit switches to the desired regulation range by lifting the knob and moving it to the desired setting (Fig. 7).

THE REGULATOR NEED NOT BE DE-ENERGIZED WHEN MAKING REGULATION ADJUSTMENTS.

DRAG HAND RESET

To reset the drag hands on the load-bonus position indicator, press the drag hand reset button on the lower left corner of the control panel. Drag hands will reset automatically.



1. Limit switch adjusting knob (lower)
2. Limit switch adjusting knob (raise)

Fig. 7. Load-bonus position indicator

THREE-PHASE CONNECTIONS

The line connections for three-phase operation are shown in Fig. 6.

Note that Type ML32 regulators cannot be operated in Y-connection with the bank-neutral isolated. When these regulators are Y-connected, the neutral of the regulator bank must be effectively connected to the system neutral, preferably by the fourth wire. Without this interconnection, Y-connection is hazardous, as the individual and independent voltage control of each phase can cause unequal turn ratios between phases, resulting in shifting of an isolated neutral with extreme distortion of phase voltages.

OVERLOADING REGULATORS

The regulator may be overloaded in accordance with the American Standard Guide for Loading Step Voltage Regulators, Appendix C57.95–1955.

OTHER THAN RATED VOLTAGE

All regulators, except those of the 2500-volt rating, are provided with taps on the potential transformer for reduced-voltage operation. These taps make it possible to obtain the proper voltage for the control circuit. When operated at other than rated voltage, the regulator KVA must be reduced unless otherwise specified on the nameplate.

With the exception of certain operating voltages for 7620-volt regulators, all ratios of potential transformers may be changed by changing the connection of lead No. 9 at terminal board located on the control panel. Other connections are to be changed inside the regulator tank. For proper connections, see regulator nameplate.

The following table lists the standard potential ratios.

RATED VOLTAGES	OPERATING VOLTAGES	POTENTIAL RATIOS	VOLTAGE LEVELS OF VOLTAGE SENSOR
2500	2500	20:1	125
5000	5000	40:1	125
	4330	34.7:1	125
	2500	20:1	125
7620	7960	66.7:1	119.3
	7620	66.7:1	114.2
	7200	60:1	120
	6900	60:1	115
	5000*	40:1	125
	4330*	34.8:1	124.4
	2500*	20:1	125
13800	13800	120:1	115
	12000	100:1	120
14400	24940GR.Y	120:1	120
	12470GR.Y	60:1	120
19920	34500	166:1	120

** Connection for these operating voltages must be made inside the tank.*

When it becomes necessary to change potential transformer connections inside the tank to obtain the correct potential ratio, remove the cover and lower the oil just enough to expose the potential transformer terminal board. (Be careful not to expose the current

transformer or bridging reactor to the air.) Remove insulation from the existing connection, and disconnect this joint. Cut the cloth tape and remove the paper insulation from the potential lead to be used in making the new connection. (The terminal board is clearly stamped to identify the potential leads.)

Make the desired connection, and re-insulate this joint. Tape the disconnected potential lead.

TEST FOR PHASE SEQUENCE

If the system phase sequence is not known, use the following method of obtaining the proper phase relationship.

The regulators carrying the leading and lagging current can be identified as outlined below. This method may be used only for two regulators in an open-delta system and should be made when the regulators are carrying appreciable load.

a. Connect the regulators for normal open-delta operation. See Fig. 6.

b. Set the control switch on "AUTO."

c. Set the resistance (R) and reactance (X) adjustments on the line-drop compensators of both units on zero.

d. Set the voltage sensor on each unit at approximately 120 volts.

e. Set X on each regulator to 10 volts, leaving R on zero. Measure the output voltages of each regulator.

f. The regulator with the higher output voltage (nearer the maximum raise position as observed on the position indicator) is on the lagging phase; the other is on the leading phase.

CHECKING REGULATOR CONTROLS

With by-pass switch "A," Fig. 3, in series with the line closed, close the disconnect switch "B" (and "D" if used) on the source side of the regulator. Do NOT close the disconnect switch "C" on the load side.

Close the control-power circuit breaker.

Set the line-drop compensator to zero compensation.

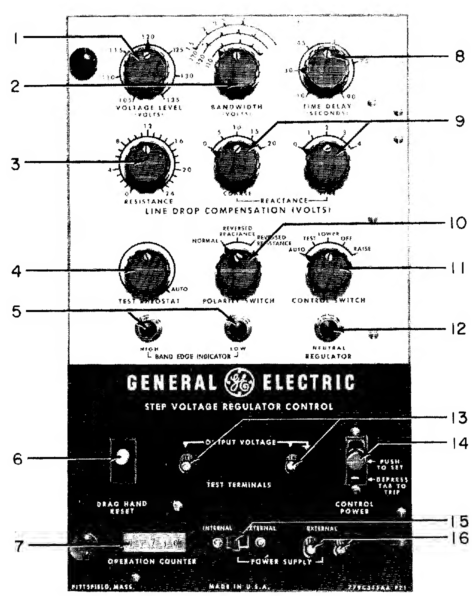
Turn the selector switch to LOWER. The regulator will make the number of steps in the LOWER direction depending upon the setting of the limit switch in the indicator; then the motor will be stopped by the opening of the "lower" limit switch.

Turn the selector switch to AUTO. After a time delay (as determined by the setting of the time-delay relay), the regulator will operate and come to rest.

Check the operation of the regulator in the RAISE direction in the same manner.

If desired, connect a precision voltmeter to the test studs on the front of the control panel. The reading should be within the bandwidth of the voltage setting of the voltage sensor.

If the setting of the voltage-sensor is satisfactory, return the regulator to NEUTRAL; then set the selector switch and the control-power circuit breaker on OFF. If unsatisfactory, adjust the voltage sensor as explained under OPERATION OF THE STATIC CONTROL.



1. *Voltage level adjustment*
2. *Bandwidth adjustment*
3. *Resistance compensator*
4. *Test rheostat*
5. *High and low lights*
6. *Reset switch*
7. *Operation counter*
8. *Time delay adjustment*
9. *Reactance compensator*
10. *Polarity switch*
11. *Control switch*
12. *Neutral light*
13. *Output test terminals*
14. *Control power circuit breaker*
15. *External power supply switch*
16. *External power supply terminals*

Fig. 8. Control panel, front view

OPERATION OF THE STATIC CONTROL

INTRODUCTION

The control described below incorporates the standard features of voltage-sensing, time delay and line-drop compensation common to all controls for step voltage regulators. All functions except the final output to the motor circuit are performed with static devices in order to minimize the effects of wear over an extended service life.

The controls are designed for 60-cycle alternating-current operation. All devices are factory calibrated and adjustments can be made by the calibrated control knobs. No warm-up time is required by the controls and the accuracy class is better than Class I. The control settings can be secured by the locking knobs.

OPERATION

The regulator output voltage is stepped down by an internal potential transformer and is applied to the input of the control. A test rheostat (R24) is provided to permit variation of the voltage applied to the sensing circuit of the control with no change in the regulator output voltage. This facilitates checking of controls at installation.

A tapped transformer (T1) is used to reduce the voltage applied to the line-drop compensator and sensing circuit to a desired level. A rheostat (R29) provides for voltage level settings between 105 and 135 volts.

Before being applied to the sensing circuit, the output of transformer (T1) is modified by the line-drop compensator. The line-drop compensator consists of a tapped reactor (L1) and a rheostat (R27) which are used to develop voltages proportional to the IX and IR drops in the line fed by the regulator. The reactor simulates the IX drop and has taps selected to permit the insertion of 0 to 24 volts compensation in one-volt steps with rated current flowing in the regulator. The resistance compensation is continuously adjustable from 0 to 24 volts at rated output current. A compensation polarity selector switch (S1) is provided to permit the reversal of either the resistance or the reactance compensation when required by regulator application. For normal compensation applications, the voltage developed across the line-drop compensator is subtracted from the regulator output voltage. This forces the regulator output to be higher for a given voltage into the sensing circuit and thus causes the regulator to compensate for the drops created by current flow in the lines.

The voltage-sensing element of the control is a zener diode bridge. The legs of the bridge consist of R6; CR21, CR22, Z1 and R12; CR19, CR20 and Z2; R28, R8, R7 and R15. Resistors R12 and R15 are relatively small and may be ignored in a general analysis of bridge operation. Diodes CR19, CR20, CR21 and CR22 are used for temperature compensation and may also be ignored for general analysis. This leaves the basic elements of the bridge being R6, Z1, Z2, R28, R8 and R7. The zener diodes serve as reference devices and voltage variations are reflected as differences in voltage across the resistors. Since zener diodes are DC devices, it is necessary to rectify and filter the regulator output before applying it to the sensing bridge. For this application, the bridge is at its balanced condition when the potential at the junction of R6 and CR21 is equal to the potential at the center of the active portion of R8. As the applied voltage increases, the potential at the center of R8 rises with respect to the potential at the junction of R6 and CR21. As it decreases the reverse occurs.

The output of the voltage-sensing bridge is fed to the control windings of a pair of magnetic amplifiers (AMP1 and AMP2). At balance, current flow in the control windings of AMP1 is from R9 to L3 and current flow in the control windings of AMP2 from L3 to R10. Current flow in this direction causes each amplifier to produce negative pulses to the gate circuit of SCR1. Since positive gate voltage is required to make an SCR conduct, there will be no output from the control. As previously described, when the applied voltage increases the potential at the center of R8 rises with respect to the potential at the junction of R6 and CR21. When the increase is sufficient to cause the potential at the lower slider of R28 to go above the potential at the junction of R6 and CR21, the current in the control winding of AMP2 will reverse. This current reversal will cause AMP2 to produce positive pulses to the gate circuit of SCR1 and make it conduct. It may be seen that the rectifiers CR9 and CR10 in the circuit of AMP2 will force it to function on the half cycle of the a-c wave when the bottom of transformer T2 is positive with respect to the top. Therefore, positive pulses from AMP2 cause SCR1 to conduct on the half cycle which applies voltage to the lower portion of the circuit and charges capacitor C4. This potential is applied through CR14 to the time delay circuit which consists basically of a uni-junction transistor (UJT1) and an RC charging network (R25 and C5).

When C5 has charged sufficiently to cause UJT1 to conduct, the pulse created by this conduction is applied to the gate circuit of SCR2 causing it to conduct. Conduction of SCR2 energizes relay K2 which, in turn, energizes the regulator operating motor in the direction which will lower the output voltage.

A similar sequence may be followed through when the applied voltage decreases. In this case, the current through the control windings of AMP1 reverses when the potential at the upper slider of R28 falls below the potential at the junction of R6 and CR21. Note that the setting of R28 determines the amount of deviation from balance required to initiate a controlling action. Therefore, R28 is the bandwidth adjustment. *See Section on "Checking The Level and Bandwidth."*

Since AMP1 functions when the top of T2 is positive with respect to the bottom, SCR1 is caused to conduct on the half cycle which energizes the upper portion of the circuit. The same timing circuit is energized, but this time through rectifier CR13. Under these conditions, when SCR2 conducts, it will energize relay K1 which will in turn operate the drive motor to raise the output voltage. Note that variable resistor R25 changes the time constant of the RC charging network and is therefore the time-delay adjustment element. Since a single timing network is used, a single adjustment provides for equal time delay for errors in either direction.

If the voltage-sensing device returns to a balanced condition before capacitor C5 is fully charged or time cycle is completed, the capacitor will discharge through the same path as the charging network.

In order to facilitate checking the control, a pair of indicator lights is provided to show when the edge of the band has been reached. To keep from unduly loading the circuit during normal operation and to extend lamp life, the circuit is arranged such that the lamps are operative only when the control selector switch is in the TEST position. This position may be used to check voltage level and bandwidth but due to circuit loading by the lamps it is necessary to put the control selector in the AUTOMATIC position to check time delay, and for normal operation.

VOLTAGE SENSOR

GENERAL

The voltage-sensing device continuously measures the output voltage of the regulator and controls the operation of the motor of the tap changer, thereby maintaining the output voltage within a preset band.

VOLTAGE LEVEL

To adjust the voltage level of the control, rotate the adjusting knob marked VOLTAGE LEVEL. The voltage level is continuously adjustable between 105 and 135 volts, with scale markings in one-volt increments.

The sensor is set at the factory for 120 volts with 1.5-volts bandwidth.

BANDWIDTH

To adjust the bandwidth of the control, rotate the adjusting knob marked "Bandwidth." The bandwidth dial is calibrated for 1.5, 2.0, 2.5 and 3.0 volts at normal voltage levels between 110 and 130 volts. The desired bandwidth is obtained by the intersection of the voltage level line and bandwidth line.

NORMAL VOLTAGE

The normal voltage setting of the voltage sensor should be checked first. Normal voltage is the median of the voltage at the point between when the HIGH and LOW band edge indicator lights just go on.

To adjust, check the normal voltage level, connect an indicating voltmeter to the potential test terminals on the control panel and set the line-drop compensator for zero compensation. The indicating voltmeter will then read the equivalent output voltage of the regulator.

CHECKING THE LEVEL AND BANDWIDTH

With the indicating voltmeter connected to the potential test terminals, proceed as follows:

1. Set the VOLTAGE LEVEL adjusting knob.
2. By means of the automatic-manual control switch, operate the regulator either RAISE or LOWER until the voltmeter reads approximately 2 volts above the upper edge of the desired regulator bandwidth.
3. Turn the CONTROL SWITCH to TEST. At this point the HIGH light should be lit signifying that the voltage is above the upper edge of the bandwidth.
4. Turn the TEST RHEOSTAT in until neither light is lit. Continue turning in the TEST RHEOSTAT until the LOW light is lit and record the voltage at which the light comes on. This is the lower edge of the bandwidth.
5. Turn the TEST RHEOSTAT in the opposite direction until the HIGH light is lit and record the voltage at which this light comes on. This is the upper edge of the bandwidth.

6. The median of these two voltage recordings is the true normal voltage setting of the control. Should this actual setting be slightly different than required, slightly adjust the VOLTAGE LEVEL control knob accordingly and repeat the above steps. Bandwidth is the interval between when the HIGH and LOW just go on.
7. Return the TEST RHEOSTAT and CONTROL SWITCH to AUTO position and reset the line-drop compensator to the desired value.

TIME DELAY

GENERAL

The TIME DELAY provides for a time delay between the energizing of the voltage-sensing device and functioning of the load-tap changing equipment. The time delay is continuously adjustable from 10 through 90 seconds. To adjust the TIME DELAY, rotate the adjusting knob indicated TIME DELAY to the desired time.

The timer is set for 30 seconds at the factory, and this is the recommended setting unless particular applications indicate otherwise.

Charging time of the capacitor depends on the length of time the timing cycle has been off. The recovery time of the timer is essentially the same as the charging or cycling time, thus the timer has an integrating action until the output relay closes at which time the timer automatically resets to zero time.

CHECKING TIME DELAY

The CONTROL SWITCH must be in the AUTO position to check time delay. Place the control in a balance condition within the bandwidth. Start of time delay is initiated when the control is instantaneously placed out of the bandwidth by use of the level adjust. The time between throwing the control out of the bandwidth and when the motor energizes is the time delay.

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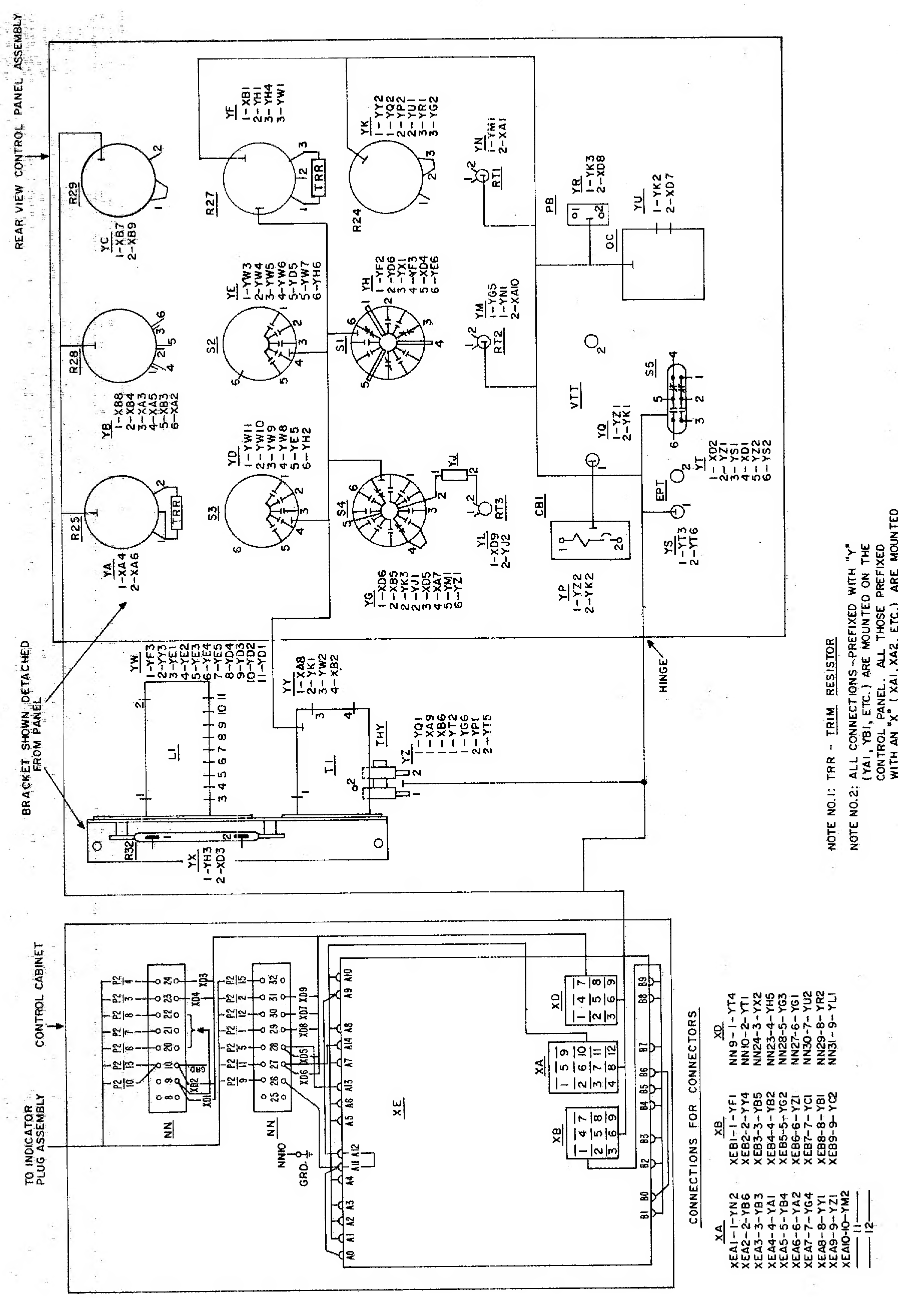


NOTE NO.1: TRR - TRIM RESISTOR

NOTE NO.2: ALL CONNECTIONS PREFIXED WITH "Y" (YA1, YB1, ETC.) ARE MOUNTED ON THE CONTROL PANEL. ALL THOSE PREFIXED WITH AN "X" (XA1, XA2, ETC.) ARE MOUNTED IN THE CABINET.

Fig. 9. Wiring diagram of control panel (G-E dwg. 777C385AB)

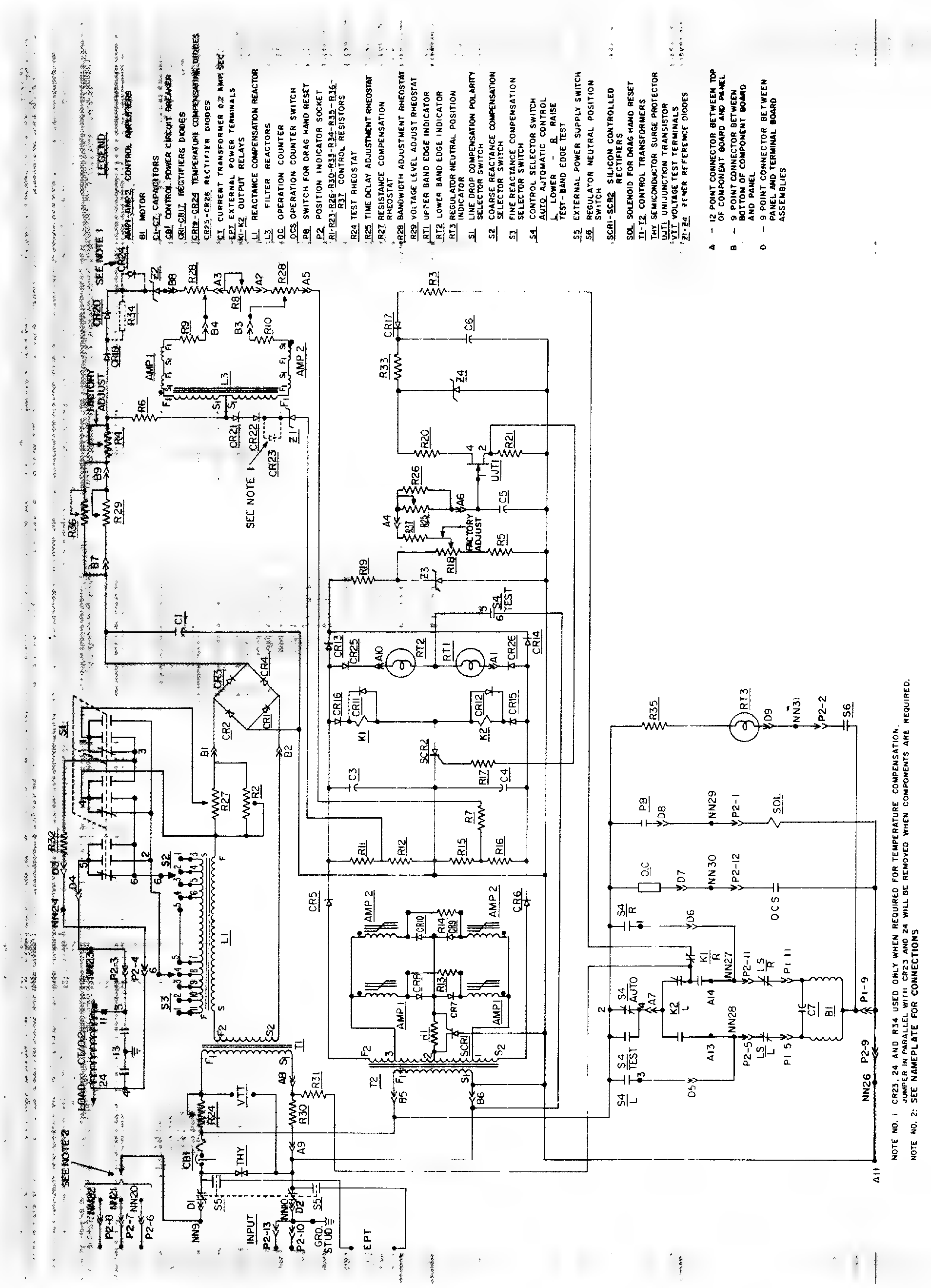
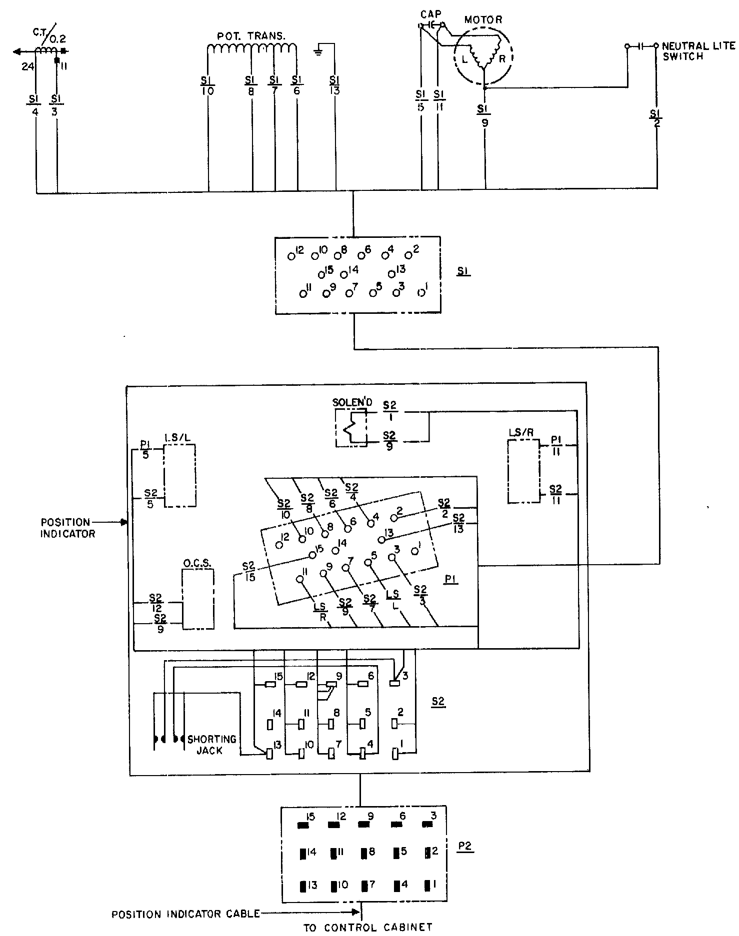


Fig. 10. Schematic diagram of control circuit (G-E dwg. 777C385AB)



POSITION INDICATOR PLUG (P2) PIN NO.	WIRE COLOR	TERMINAL BOARD CONNECTION (NN)
1	RED / WHITE	29
2	BLUE / WHITE	31
3	BLACK (# 20 AWG)	23
4	WHITE (# 20 AWG)	24
5	GREEN	28
6	ORANGE / BLACK	20
7	ORANGE	21
8	BLUE	22
9	GREEN / BLACK	26
10	BLUE / BLACK	10
11	RED	27
12	RED / BLACK	30
13	WHITE (# 16 AWG)	10
14	N. C.	
15	BLACK (# 16 AWG)	32

Fig. 11. Wiring diagram, position indicator and auxiliary devices (G-E dwg. 777C385AB)

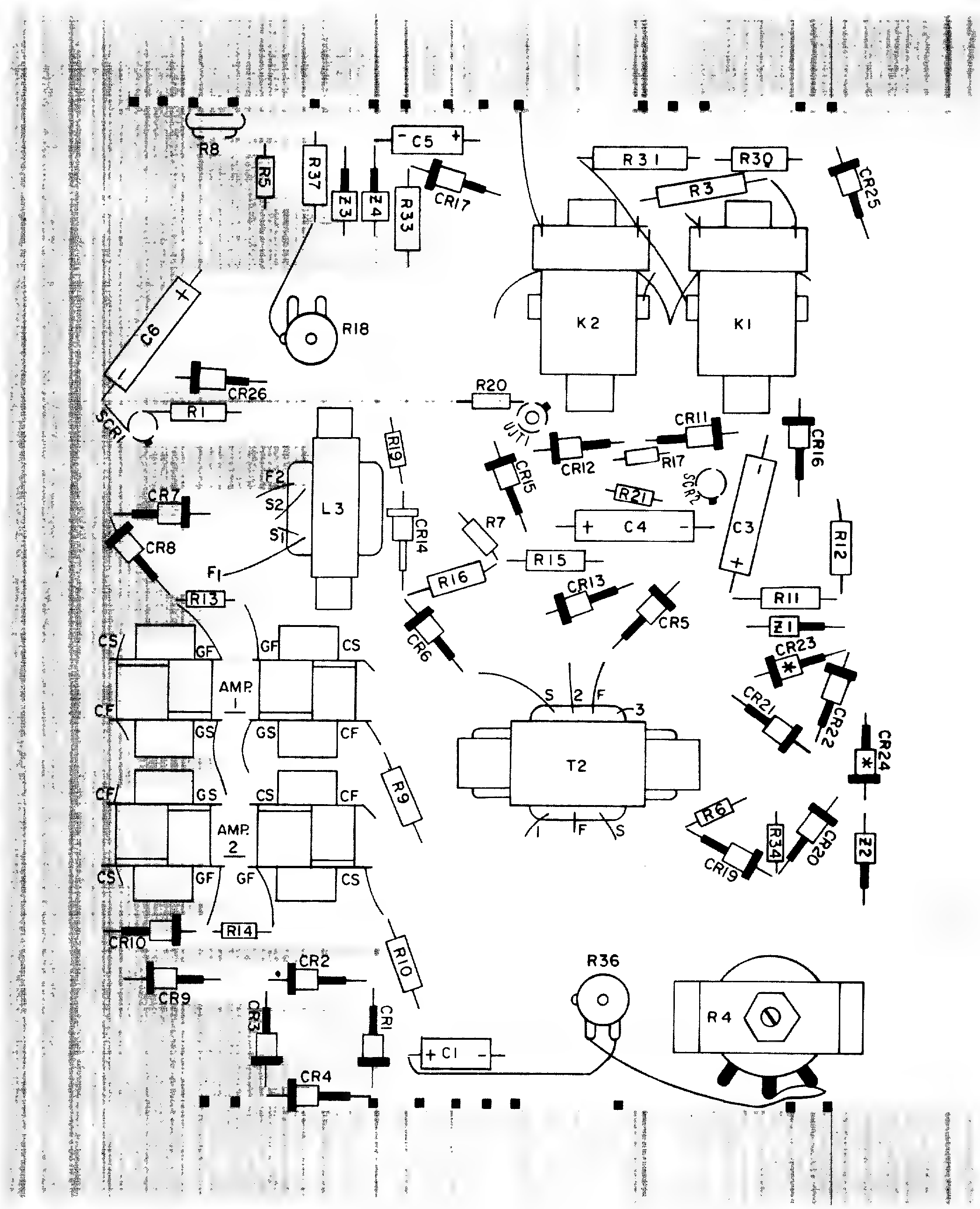


Fig. 12. Component board layout

LINE-DROP COMPENSATOR

The Line-Drop Compensator has adjustable positive resistance and reactance elements in the control circuit which make it possible to simulate actual line impedance. The reactance setting consists of a coarse and fine adjustment knobs. A combination of these adjustments provides a range of 0 to ±24 volts.

A line current transformer inside the regulator causes a proportional current to flow through the R and X of the compensator circuit. The compensator IZ drop is subtracted from the potential transformer secondary voltage, and the resultant is applied to the voltage sensor. This sensor causes the regulator to hold a voltage high enough (or low enough) to compensate for the voltage drop (or rise) to some predetermined location on the line, thus causing the voltage at this point to remain essentially constant. The settings of the line-drop compensator are calculated using the equations shown on page 20.

For single-phase (2-wire) circuits double the assumed R and X values, as the total impedance out and back must be factored. If the circuit consists of one line and a grounded neutral, the total will be 1.67 times the assumed R and X values. For three-phase circuits the loads are assumed to be balanced, and the impedance for one wire only need be considered.

Sample calculations which illustrate how these equations are applied for various circuit configurations and regulator connections are shown on page 20. The line resistance, reactance and current transformer primary rating may be obtained from Tables 1 and 2.

It should be kept in mind that with delta or open-delta connected regulators the settings obtained from the calculations must be modified as illustrated in Case IIIA of the sample calculations.

$$\textit{R setting (volts)} = \frac{I_cT^* \times \textit{resistance of the line (ohms)}}{\textit{Potential transformer ratio}}$$

$$\textit{X setting (volts)} = \frac{I_cT^* \times \textit{reactance of the line (ohms)}}{\textit{Potential transformer ratio}}$$

*I_cT = *Current transformer primary current rating*

TABLE 1

RESISTANCE AND REACTANCE OF OPEN WIRE CIRCUITS PER SINGLE CONDUCTOR IN OHMS PER 1000 FEET AT 60 CYCLES

COPPER - HARD DRAWN

WIRE SIZE	RESISTANCE AT 25C	REACTANCE — EQUIVALENT SPACING OF CONDUCTORS*							
AWG		18"	24"	30"	36"	42"	48"	54"	60"
8	.656	.135	.142	.147	.151	.155	.158	.161	.163
6	.413	.130	.137	.142	.146	.150	.153	.156	.158
4	.263	.124	.130	.135	.140	.143	.146	.149	.151
2	.167	.119	.125	.130	.135	.138	.141	.144	.146
1	.132	.115	.122	.127	.132	.135	.138	.141	.143
1/0	.105	.113	.120	.125	.129	.132	.136	.138	.141
2/0	.083	.110	.117	.122	.127	.130	.133	.136	.138
3/0	.066	.108	.114	.119	.124	.127	.130	.133	.135
4/0	.053	.105	.111	.116	.121	.124	.127	.130	.132
MCM									
250	.045	.103	.108	.113	.118	.121	.124	.127	.129
300	.037	.098	.106	.111	.115	.119	.122	.125	.127
350	.032	.096	.104	.109	.113	.117	.120	.123	.125
500	.023	.095	.101	.107	.111	.114	.117	.120	.123
750	.016	.092	.098	.103	.107	.111	.114	.117	.119
1000	.012	.088	.095	.100	.104	.108	.111	.114	.116

ALUMINUM - STEEL REINFORCED

WIRE SIZE	RESISTANCE AT 25C	REACTANCE — EQUIVALENT SPACING OF CONDUCTORS*							
AWG		18"	24"	30"	36"	42"	48"	54"	60"
6	.675	.132	.138	.143	.147	.151	.154	.157	.159
4	.425	.126	.133	.138	.142	.146	.149	.152	.154
2	.267	.122	.129	.134	.138	.142	.145	.148	.150
1/0	.168	.118	.125	.130	.134	.138	.141	.144	.146
2/0	.134	.116	.123	.128	.132	.136	.139	.142	.144
3/0	.106	.114	.121	.126	.130	.134	.137	.140	.142
4/0	.084	.112	.119	.124	.128	.132	.135	.138	.140
MCM									
266.8	.066	.098	.104	.109	.113	.117	.120	.123	.125
336.4	.053	.094	.101	.106	.110	.114	.117	.120	.122
397.5	.045	.093	.099	.105	.109	.112	.115	.118	.120
477.0	.037	.091	.097	.102	.106	.110	.113	.116	.118
556.5	.032	.089	.096	.101	.105	.108	.112	.114	.117
795.0	.022	.085	.092	.097	.101	.105	.108	.110	.113
954.0	.019	.084	.090	.095	.099	.103	.106	.108	.111
1272.0	.014	.079	.086	.091	.095	.099	.102	.105	.107

*THE ROOT AVERAGE OF THE DISTANCE BETWEEN CENTERS OF CONDUCTORS

TABLE 2

Regulator Current Rating	25	50	75	100	150	200	219	250	300	334		
C.T. Primary Current Rating	25	50	75	100	150	200	250	250	300	400		
Regulator Current Rating	394	400	438	500	548	666	668	833	1000	1250	1332	1665
C.T. Primary Current Rating	400	400	600	600	600	600	600	800	1200	1200	1600	1600

SAMPLE CALCULATIONS

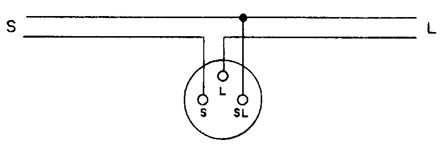
ASSUME CIRCUIT IMPEDANCE VALUES OUT TO LOAD CENTER TO BE: R = 1.5 ohms X=2.0 ohms

CASE I

Single-phase circuit
2500-volt PT Ratio 20:1
CT Primary rated 100 amps.

$$R \text{ setting} = \frac{IcT}{PT} \times 2R = \frac{100}{20} \times 3 = 15 \text{ volts}$$

$$X \text{ setting} = \frac{IcT}{PT} \times 2X = \frac{100}{20} \times 4 = 20 \text{ volts}$$

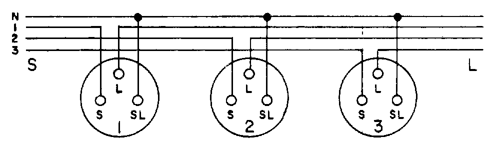


CASE II

2500/4330Y-volt, 3-phase circuit
Three, Single-phase regulators connected line to neutral.
PT Ratio 20:1
CT Primary rated 100 amps.

$$R \text{ setting} = \frac{IcT}{PT} \times R = \frac{100}{20} \times 1.5 = 7.5 \text{ volts}$$

$$X \text{ setting} = \frac{IcT}{PT} \times X = \frac{100}{20} \times 2.0 = 10 \text{ volts}$$

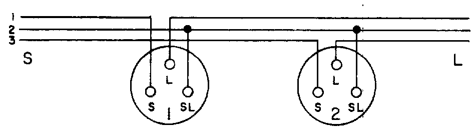


CASE III A

2500-volt, 3-phase, 3-wire circuit
Two, single-phase regulators connected in an open delta bank.
PT Ratio (line to line) 20:1
CT Primary rated 100 amperes
Convert the PT ratio to a line to neutral basis.

$$R \text{ setting} = \frac{IcT}{PT/\sqrt{3}} \times R = \frac{100}{20/1.73} \times 1.5 = 13 \text{ volts}$$

$$X \text{ setting} = \frac{IcT}{PT/\sqrt{3}} \times X = \frac{100}{20/1.73} \times 2 = 17.3 \text{ volts}$$



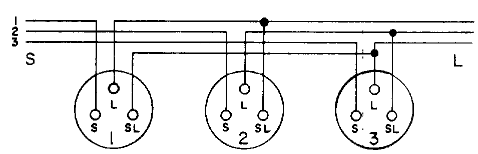
With two regulators in open delta there is a 30° phase displacement between the PT (line to line) voltage and the line current. The current lags in one regulator and leads in the other. Further modifications are necessary. Determine which is the "lead" and which is the "lag" regulator from directions on page 11.

The basic L.D.C. settings should be modified as follows:

Lead Regulator	Lag Regulator
R mod = 0.866R + 0.5X =	0.866R - 0.5X
(0.866(13) + (0.5)(17.3) = 19.9 volts	(0.866)(13) - (0.5)(17.3) = 2.6 volts
X mod = 0.866X - 0.5R =	0.866X + 0.5R
(0.866)(17.3) - (0.5)(13) = 8.4 volts	(0.866)(17.3) + (0.5)(13) = 21.4 volts

For minus values of R or X set compensator polarity switch to correspond.

CASE III B



Three, single-phase regulators connected in a delta bank.
PT Ratio (line to line) 20:1.
CT Primary rated 100 amps.
Convert the PT ratio to a line to neutral basis.

Compute the basic L.D.C. settings exactly the same as for Case III A above. All three regulators either "lead" or "lag" depending upon the phase rotation of system voltages. From directions on page 11 determine whether the regulators "lead" or "lag". Then modify the basic settings for "lead" or "lag" per instructions under Case III A.

REGULATOR FOR GROUNDED-Y CIRCUITS

The step voltage regulator rated 19920/34500 volts is designed for use on 34500 grounded-Y circuits. This regulator is designed with two 34.5-kv class line bushings (S and L) for use on circuits limited to 150-kv BIL. The neutral is brought to a 15-kv bushing (SL).

Regulators rated 14400/24940 volts are designed for use on either 14400 delta or 24940 Grounded-Y circuits. A tap is provided for operation at 7200 volts delta or 12470 Y operation at reduced capacity. The current rating of the regulator must not be exceeded when operating at the lower voltages.

The regulator is designed with two 25-kv class line bushings (S and L) and a 15-kv class neutral bushing (SL).

When operating on a 25-kv or 34.5-kv circuit, the SL bushing must be solidly grounded or grounded through an impedance that will limit the low frequency and impulse from neutral to ground to the 15-kv insulation class.

REGULATOR CONNECTIONS

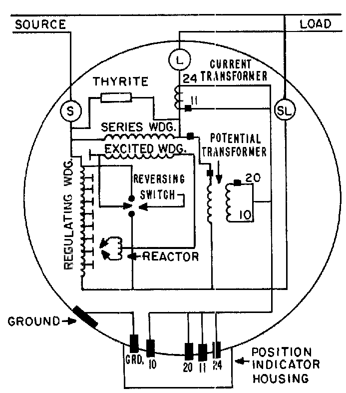


Fig. 13A. Schematic diagram showing two-core regulator with a series transformer

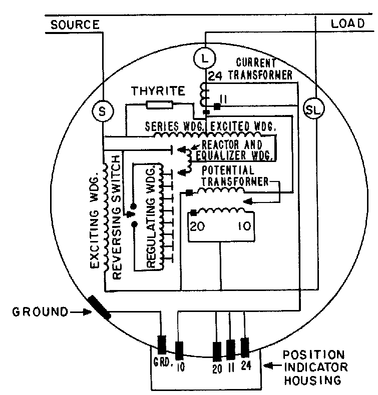


Fig. 13B. Schematic diagram showing two-core regulator with a series autotransformer

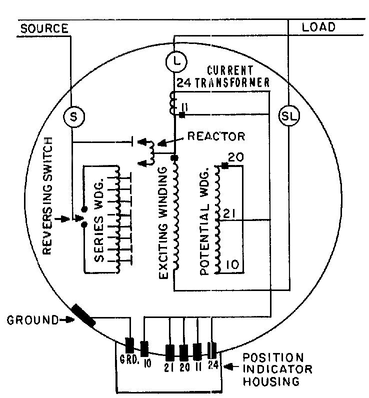


Fig. 13C. Schematic diagram showing connections of regulator for GRDY circuits

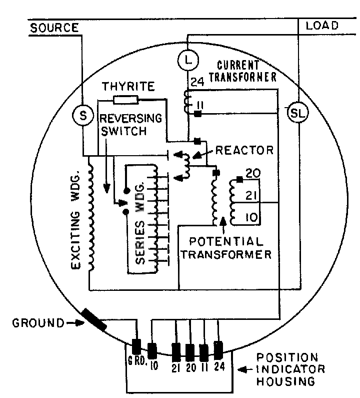


Fig. 13D. Schematic diagram showing single-core regulator

TROUBLE-SHOOTING CHART

TROUBLE	CAUSE	REMEDY
I. Regulator will not operate either automatically or manually or remains in maximum lower or maximum raise position.	1. Loss of sensing signal from the regulator.	1. Using an AC voltmeter check for control sensing voltage at the voltage test terminals. If no voltage at this point, either the external power supply switch or the circuit breaker is defective. Check for sensing voltage between NN9 and NN10. If no voltage appears at these terminals, the problem is outside the controls. If voltage does appear at this point, check for faulty external power supply switch or a faulty circuit breaker.
	2. Motor circuit is not functioning properly or the control switch may be defective.	2. If correct voltage is measured at the voltage test terminals, place the control switch to raise position (check to be sure the regulator is not in the maximum raise position). Place an AC voltmeter (150-volt scale between NN27 and NN26. If voltage is not measured here, the control switch is faulty. If voltage does appear here, the motor circuit is defective.
	3. Indicator switches are not operating properly.	3. See page 26 for removing indicator dial.
II. Regulator functions manually but not automatically in either the raise or lower direction.	1. Loss of sensing voltage to the bridge rectifier or the zener bridge which are located on the component board assembly. 2. Defective relay voltage supply.	1. & 2. Check sensing circuits and relay voltage supply circuits as follows: Set the control switch to "Test" observing the band edge indicator lights, with 120 volts supplied to the control, from either the internal regulator supply or from an external source connected to the terminal marked "External" and power supply switch to position marked "External." Vary the level adjustment in and out of the bandwidth in both above and below 120 volts by use of the level adjust control. If the lights indicate the correct voltage level, voltage supply to the relay is correct. If not, problem lies in these circuits. Elimination of level adjust rheostat would isolate the problem to the component board. This may be accomplished by disconnecting the "B" (9 point connector) plug assembly between the component board and the panel. CAUTION: Turn off power before disconnecting. With an analyzer check the level adjust rheostat R29 for a range of 0-425 ohms $\pm 10\%$. Also check continuity between panel ground and rheostat terminals to make sure terminals are not grounded. Replace rheostat if defective. If rheostat agrees with correct range and ground test, sensing circuits located on board are defective. Replace component board.
	3. Defective Time Delay Circuit.	3. If the timing circuit does not function, the silicon rectifier SCR 2 will not conduct and complete the ground circuit for the relays. Test the time delay rheostat R25 similar to the level adjust test as above except the range will be from 0 to 2.5 megohms $\pm 10\%$. Replace rheostat if defective. If rheostat is normal, problem will be located on the board assembly. Replace component board.

TROUBLE-SHOOTING CHART (Continued)

TROUBLE	CAUSE	REMEDY
III. Regulator runs to maximum Raise or maximum Lower limit.	1. Defective Relays or Sensing Circuits.	1. If sensing circuits are functioning properly, check for sticking relays. Replace relays, if defective. Caution should be taken when relays are removed from the board. All connections from the relay to the board should be disconnected at the relay and not the board.
IV. Incorrect level or Control cannot be balanced.	1. Defective Sensing Circuits.	1. Check circuits as in II above.
	2. Position indicator plug not fastened securely.	2. If the position indicator plug is not fastened securely so the shorting pin is not spreading the CT shorting jack to break the short, a grounding of either side of the CT will result depending on the position of the ground in the circuit. An increase of input voltage by approximately 6 volts will be necessary to balance. (i.e., Control level set for 120, balance will occur at approximately 126 volts), or the control cannot be balanced. Check indicator plug for proper alignment or interference and fasten securely.
V. Regulator operates frequently.	1. Incorrect bandwidth.	1. With selector switch in the "Test" position, check bandwidth setting by using band edge indicators and an A.C. voltmeter at the voltage test terminals. See bandwidth check in control settings under "Operation of Static Control," page 13. To check the band rheostat, disconnect power, then disconnect the "B" plug (9 point connector). With an analyzer check the resistance of each layer of the bandwidth rheostat R28. Each layer should be 25 ohms $\pm 5\%$. Also check for shorting between the panel ground and terminals of each layer. Replace bandwidth rheostat, if defective. If rheostat is normal, replace the component board.
	2. Time Delay setting is too low or the circuits are malfunctioning.	2. The control switch must be in the "Auto" position to check time delay. Place the control in a balanced condition within the bandwidth. Start of time delay is initiated when the control is instantaneously placed out of the bandwidth either by use of the level adjust or the test rheostat. The time between throwing the control out of the bandwidth and when the motor energizes is the time delay. If this is drastically different ($\pm 20\%$) from the calibrated setting, the time delay circuit is malfunctioning. Remove component board and return for replacement.
VI. Regulator bucks when load increases.	1. Reversed polarity in either the current transformer or potential transformer.	1. Reverse the current transformer leads in the control cabinet in this manner: Disconnect leads No. NN24 and NN23 (on current transformer resistor) and reverse connections. WARNING: Short-circuit current transformer so that the secondary will not become open-circuited. (Current transformer is short-circuited automatically by removing indicator plug from indicator.)

TROUBLE-SHOOTING CHART (Continued)

TROUBLE	CAUSE	REMEDY
VII. Line Drop Compensator is not functioning in either reactance or resistance or both.	1. Shorting jack in the indicator plug is not open.	1. Remove the indicator plug and check the shorting pin for physical defects. If defective, replace. If shorting pin is normal, reconnect indicator plug and secure tightly to be sure the shorting pin is disengaging the shorting jack.
	2. R32 is defective.	2. Disconnect the indicator plug and "B" connector (9 point plug) within the control cabinet. With an analyzer, check the resistance of R32. A value of 150 ohms ±10% should be measured. If not, resistor is defective and should be replaced.
	3. S1, S2 or S3 is defective.	3. With the indicator plug and "B" connector disconnected, measure the resistance between NN23 and NN24 with an analyzer. With both compensator controls set at zero, the resistance of R32 (150 ohms) would be measured again. If not, either S1, S2 or S3 may be defective. Check each switch for corrosion or mechanical defects. If defects exist, replace the particular switch. Switching to all positions on each switch would aid in determining fault.
	4. Defective Rheostat R27.	4. With the indicator plug and "B" connector disconnected, measure the resistance between the slide arm and one end terminal. Vary the rheostat from one extreme to the other, a variation of 24 ohms ±1% should be noted. If not, rheostat is defective and should be replaced.
	5. Defective Current Transformer.	5. I. all components in 1, 2, 3 and 4 are normal, but no compensation exists, a defective current transformer is the probable cause.
VIII. Motor does not operate.	1. Motor or motor capacitor may be faulty.	1. Disconnect the four leads from the capacitor terminals, apply 240 volts, 60 cycles to the terminals, and read the current in the line. This reading should be approximately 0.36 amperes. Discharge the capacitor before reconnecting the leads.
	2. Motor may be faulty.	2. Reconnect capacitor, apply 120 volts directly to the motor. Refer to Control Diagram for connections.

MAINTENANCE

INSPECTION

At regular intervals, as determined by service, inspect the regulator to make sure it is operating properly and to detect and correct any trouble which may interfere with efficient service.

To check the operation, it is not necessary to untank the regulator. Run the regulator to its "Raise" and "Lower" limit positions by using the manual control switch to test the limit switches.

By manual control, run the regulator in either direction a few steps, and then turn the regulator back to AUTO to check the voltage sensor. After a time delay (30 seconds as set at the factory) the tap selector will operate and come to rest.

The devices in the control cabinet require very little maintenance.

If the control has to be removed from the regulator pull the plug from the socket assembly, which is mounted under the indicator. The regulator can remain energized, as the current transformer is automatically short-circuited by a shorting jack on the socket assembly when the plug is removed.

UNTANKING

To untank the regulator, follow the procedure outlined below.

***WARNING:** De-energize the regulator before untanking.*

***WARNING:** Always release any possible pressure in the tank (which may accummulate due to loading-cycle or ambient-temperature change) by slowly loosening the handhole coverband. DO NOT attempt to remove the cover or handhole cover until the pressure has been released.*

1. Remove the handhole cover.
2. Disconnect the bushing cables.
3. Remove the cover band, and lift off the cover.
4. Disconnect the plug inside the regulator tank at the indicator.
5. Disconnect the position indicator flexible cable at the indicator.
6. Remove the tanking bolts at top of unit.
7. Lift the regulator from the tank, using the holes at the top of the uprights.

When lifting the regulator from the tank, the use of a spreader bar is recommended. See Fig. 14.

8. When retanking the regulator, follow the reverse procedure outlined above except when replacing cover, tap cover with rubber hammer around the edge to properly seal gasket while tightening coverband.

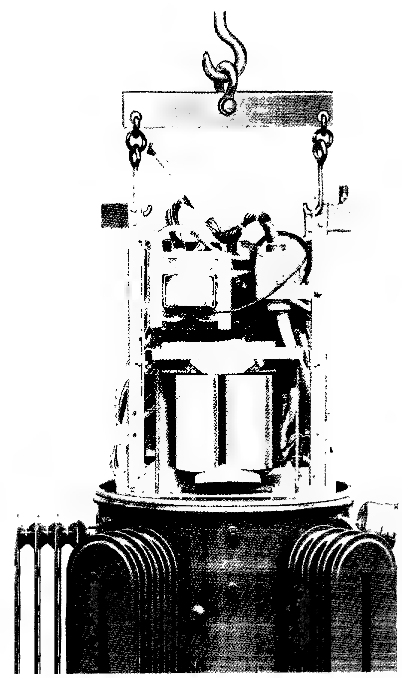


Fig. 14. Untanking Type ML32 step voltage regulator. Showing use of spreader bar when lifting regulator from tank.

9. Position-indicator pointer should be centered on "O" before connecting shaft to the mechanism. For indexing the indicator, move flexible shaft

When regulator is untanked, the mechanism may be operated by applying 120 volts to terminals (25) or (26) on motor capacitor and No. 10 lead. Connection to No. 10 lead is made on the exposed terminal which is tied to the insulated mechanism spacer.

Caution should be exercised not to run the mechanism beyond the maximum RAISE or LOWER position since the electric limit switches (in the position indicator) are out of the circuit now.

A yellow mark inside the regulator tank indicates the level at which the oil should be maintained at all times. Check the dielectric strength of the oil, and, if found to be 22 kv or below, filter the oil to restore its dielectric strength to 26 kv or more.

REPLACING INTERNAL CLAMP BUSHING

Remove the main cover from the regulator and disconnect the bushing cable. Loosen the three screws on the holder and remove the garter spring. Bushing can now be removed from the cover.

Replace bushing using the reverse procedure. When tightening the holder screws, equalize the torque on all three screws.

REMOVING INDICATOR DIAL ASSEMBLY

Disconnect the cable and plug assembly from the position indicator. Loosen the three thumb screws and open indicator glass assembly. Remove three self-tapping screws located on outside perimeter of the dial face. Carefully pull out dial assembly which contains pointer, drag-hand assemblies and limit switches. The operation counter switch and drag-hand solenoid will be exposed when the dial assembly is removed. To remove dial assembly completely, remove the flag terminal from the limit switches.

CONTACT INSPECTION

The table which follows is given as a guide for inspecting the contacts of your regulator on the basis of minimum life. It should be used for the first inspection. It is recognized that many variables affect the contact life, such as load factor, overload, service, short-circuit, etc.

Total contact life can be determined after this inspection on the basis of the amount of arcing material left in proportion to that which has been eroded.

The wiping surfaces of the moving contacts of the tap-selector switch, when new, are $\frac{3}{8}$-inch wide. The surfaces of the stationary contact arc-resisting material are $\frac{3}{16}$-inch wide.

The contacts are satisfactory for service until the moving contact is reduced almost to a line contact.

Refer to regulator nameplate for rating, and determine the contact inspection point from the chart.

EXPECTED MINIMUM NUMBER OF OPERATIONS USED AS A GUIDE FOR CONTACT REPLACEMENT ON BASIS OF CURRENT IN TABULATION BELOW

KVA	VOLTS	AMP	LIFE	INSPECT
100	2500	400	1,650,000	1,250,000
100	5000	200	1,530,000	1,150,000
114.3	7620	150	2,000,000	1,500,000
125	2500	500	1,114,000	850,000
125	5000	250	1,210,000	900,000
138	13800	100	1,460,000	1,100,000
144	14400	100	2,000,000	1,500,000
167	2500	668	815,000	610,000
167	5000	334	1,910,000	1,425,000
167	7620	219	1,150,000	865,000
200	19920	100	2,000,000	1,500,000
250	2500	1000	2,000,000	1,500,000
250	5000	500	735,000	550,000
250	7620	328	820,000	615,000
288	14400	200	1,150,000	865,000

On the same basis, other ML32 regulators rated less than 100 kva can operate in excess of 1,000,000 tap changes before inspection is required. This will be more than 25 years for normal service.

PARTS LIST

Furnish your nearest General Electric Sales Representative with *ALL* of the following information:

REGULATOR SERIAL NUMBER (found on regulator nameplate)

TYPE OF REGULATOR (All parts of this book are for Type ML32, single-phase step voltage regulators of standard design.)

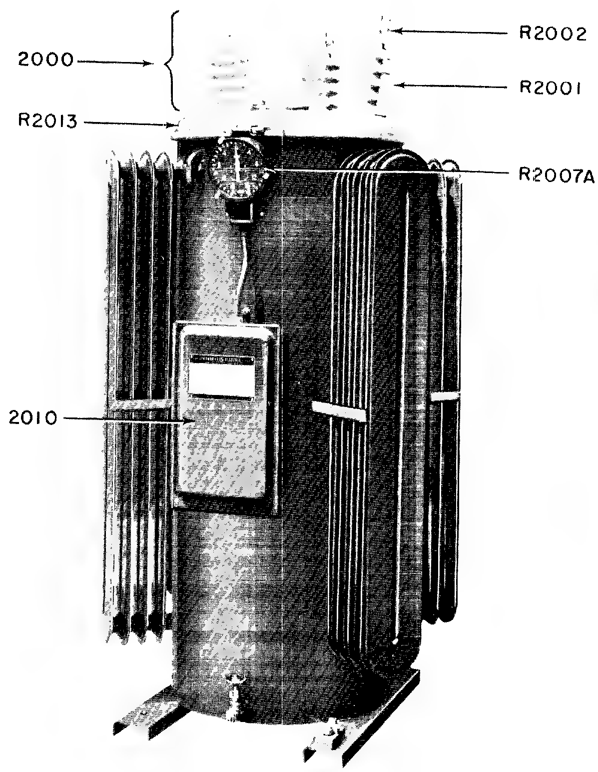
QUANTITY OF EACH PART REQUIRED

REFERENCE NUMBER OF EACH PART (as shown in *this book*)

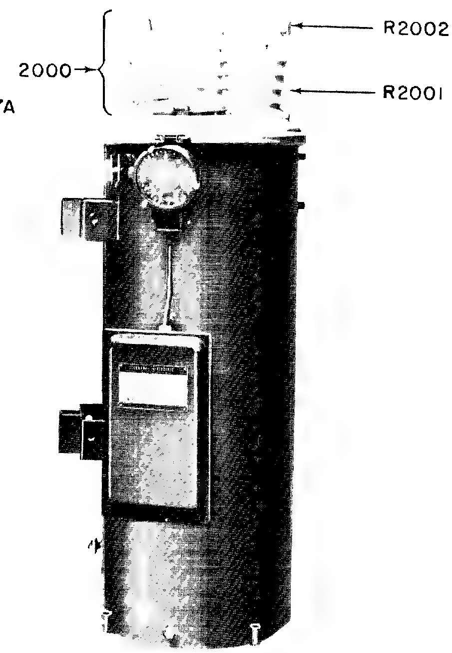
DESCRIPTION OF EACH PART (as shown in *this book*)

The General Electric "Triple-R" Parts Service Program offers you extra-swift shipment of common replacement items. Regulator parts shown in this book having reference numbers prefixed by the letter "R" will be on their way to you within 48 hours of the receipt of your order at our factory.

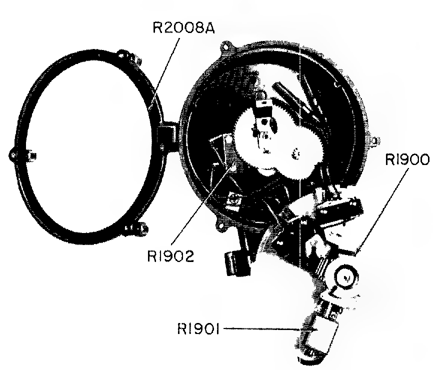
NOTE: Shipment of parts *NOT* bearing the "R" prefix will be dependent upon the availability of the parts requested. In cases where "R" parts and "non-R" parts appear on the same order, you will receive two shipments, *UNLESS YOU SPECIFICALLY REQUEST THAT A SINGLE SHIPMENT BE MADE.* Should you request single shipment, any parts bearing the "R" prefix will *not* receive Triple-R Rapid Parts Service.



Station type



Pole type



Load-bonus position indicator

FIG. NO.	REF. NO.	DESCRIPTION
15	2000	High-voltage bushing assembly—complete
15	R2001	Bushing porcelain
15	R2002	Bushing terminal
†	R2003	Bushing terminal gasket
†	R2004	Bushing cover gasket
†	R2005	Hand-hole gasket
†	R2006	Cover gasket
15	R2007A	Load bonus position indicator
15	R2008A	Load bonus indicator glass assembly kit
†	R2009	Indicator gasket
15	2010	Control cabinet assembly
†	R2011	Sampling plug
15	R2013	Cover band
15	R1900	Indicator dial and switch assembly
15	R1901	Solenoid
15	R1902	Counter switch

† Not illustrated.

Fig. 15. Type ML32 step voltage regulators

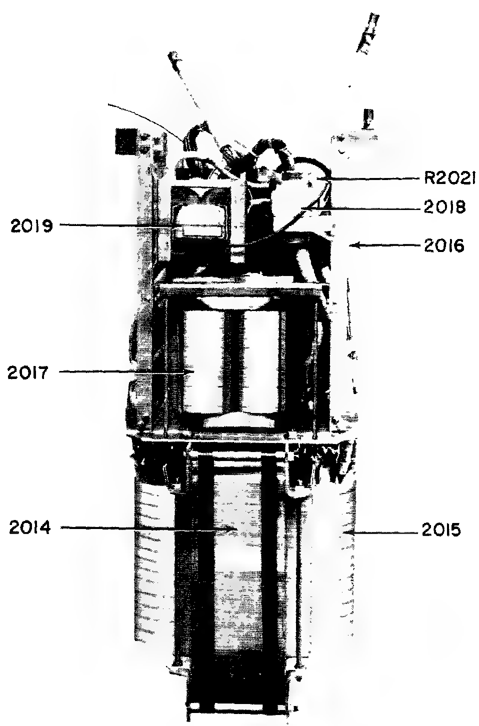


Fig. 16. Type ML32, reactor side

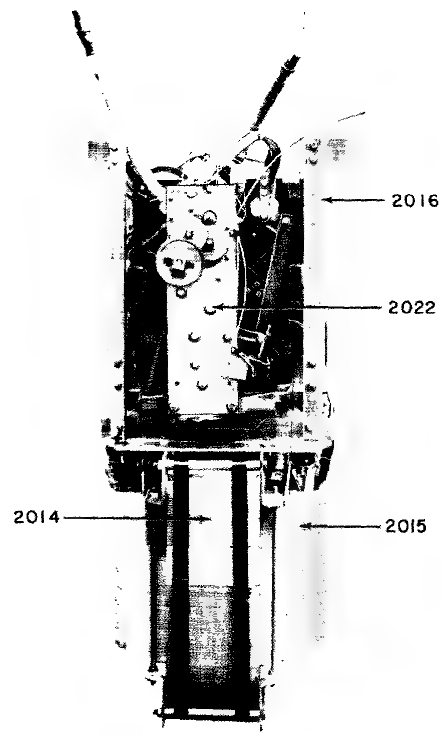


Fig. 17. Type ML32, mechanism side

Fig. 18. Pole-type hangers

FIG. NO.	REF. NO.	DESCRIPTION
16-17	2014	Core
16-17	2015	Coil
16-17	2016	Clamps
16	2017	Reactor
16	2018	Current transformer
16	2019	Pot transformer
†	2020	Thyrite assembly
16	R2021	Thyrite disks
17	2022	Switch mechanism
18	R2139	Pole-type hangers

† *not shown.*

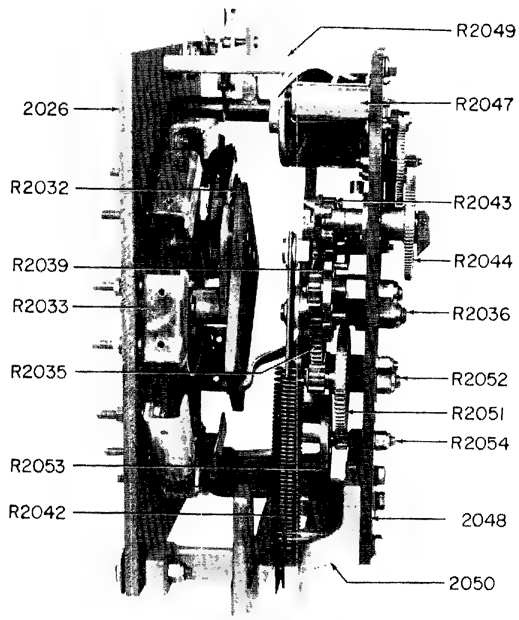


Fig. 19. High current switching mechanism

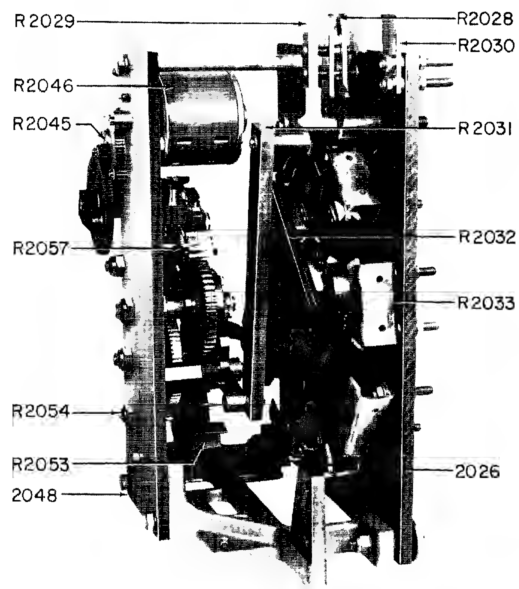


Fig. 20. High current switching mechanism

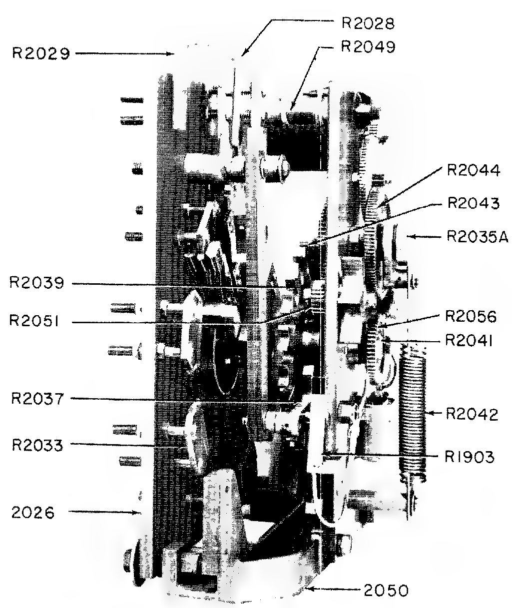


Fig. 21. Low current switching mechanism

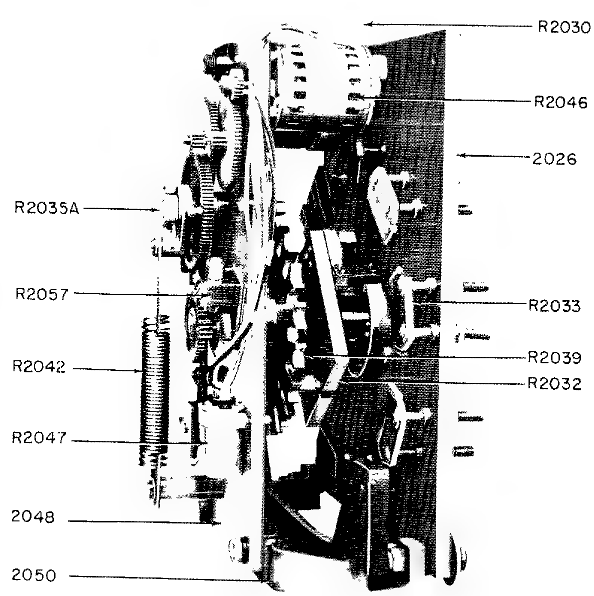


Fig. 22. Low current switching mechanism

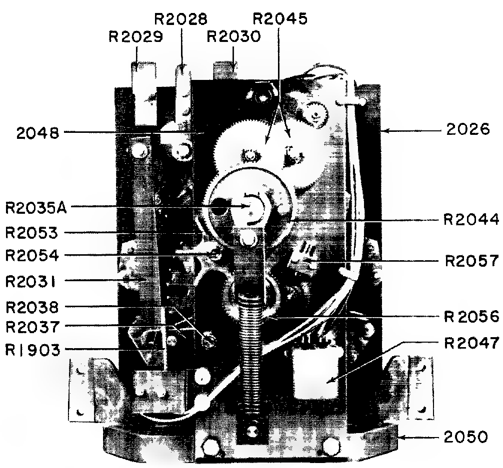


Fig. 23. Low current switching mechanism

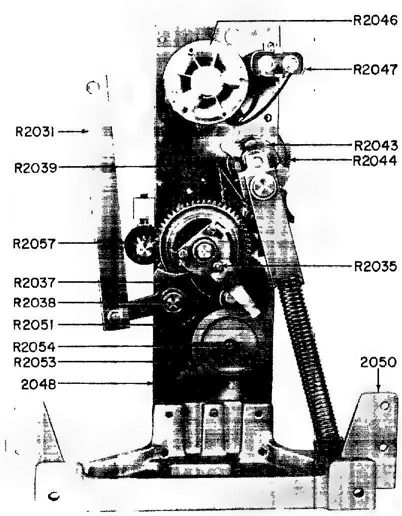


Fig. 24. High current switching mechanism

FIG. NO.	REF. NO.	DESCRIPTION
21-22-23	2026	Contact panel assembly
25	2027	Slip ring assembly
20-21-23-25	R2028	Reversing switch moving contact assembly
20-21-23-25	R2029	Reversing switch stationary contact assembly (lower)
21-22-23-25	R2030	Reversing switch stationary contact assembly (raise)
23-24-25	R2031	Reversing switch connector rod
20-22-25	R2032	Moving contact assembly
21-22-25	R2033	Stationary contact assembly
25	R2034	Moving contact stud
19-24-25	R2035	Crank gear assembly
21-22-23-25	R2035A	Crankshaft assembly
25	R2036	Shaft for crank gear
23-24-25	R2037	Geneva segment
24-25	R2038	Shaft for Geneva segment
23-25	R2039	Geneva gear and shaft assembly
25	R2041	
19-21-22-25	R2042	Crank and spring assembly
19-24-25	R2043	Driver
21-23-24-25	R2044	Gear
20-23-25	R2045	Gears
22-24-25	R2046	Motor and pinion
22-23-24	R2047	Capacitor
22-23-24	2048	Motor drive panel assembly
19-21	R2049	Spacer assembly
21-22-23-24	2050	Base
19-21-24	R2051	Impeller gear
19-25	R2052	Shaft for impeller gear
21-23	R1903	Neutral light switch assembly
23-25	R2054	Shaft for impeller
20-22-23-24	R2057	Indicator miter gear assembly
25	R2058	Flexible shaft

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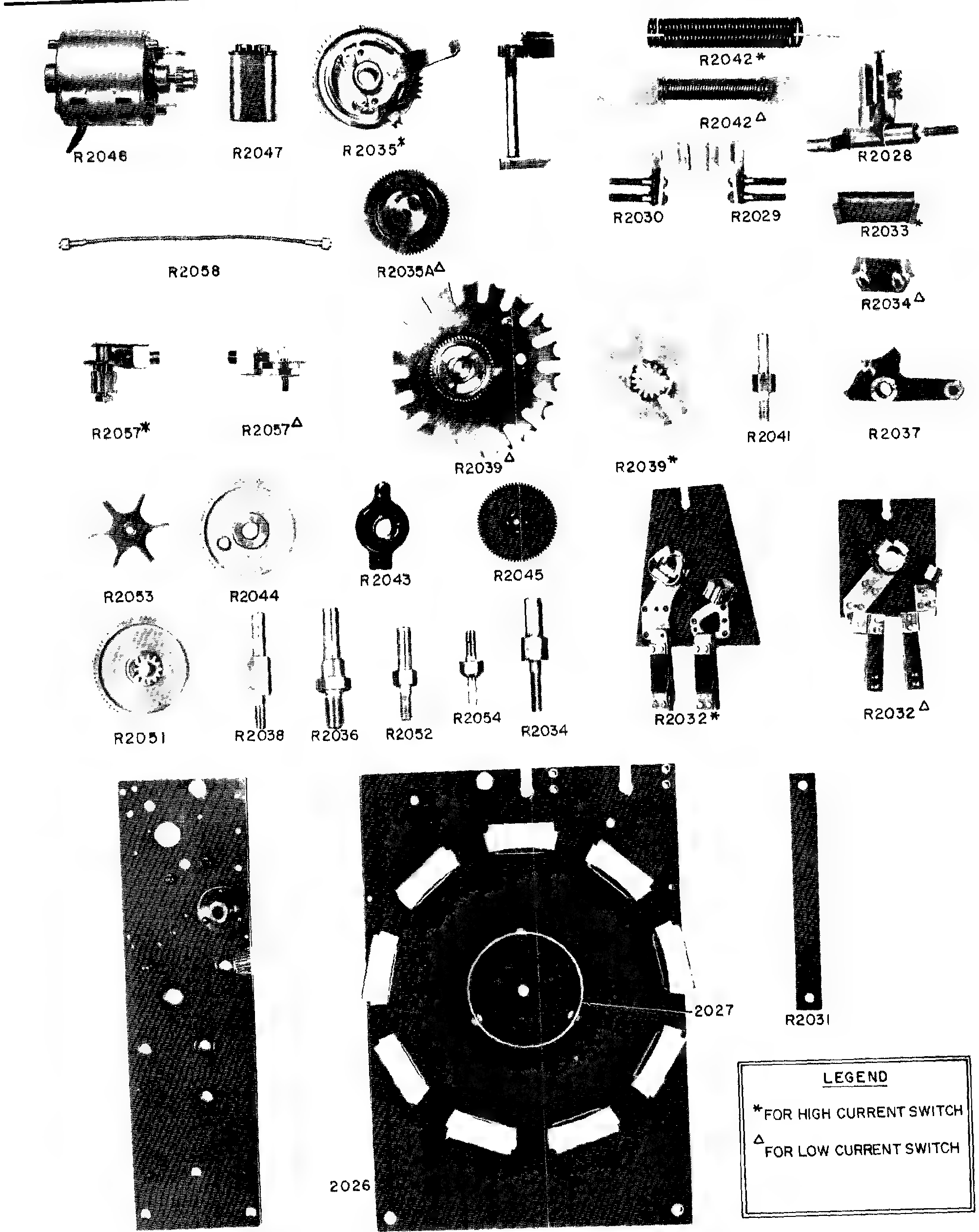

Fig. 25. Parts for switching mechanisms

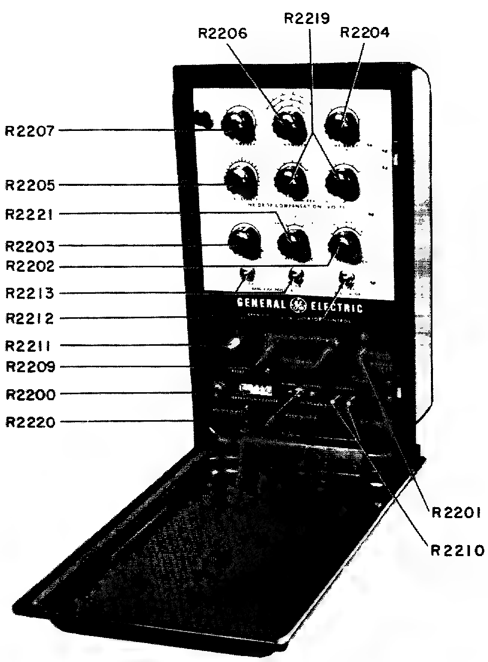

Fig. 26. Control panel, front view

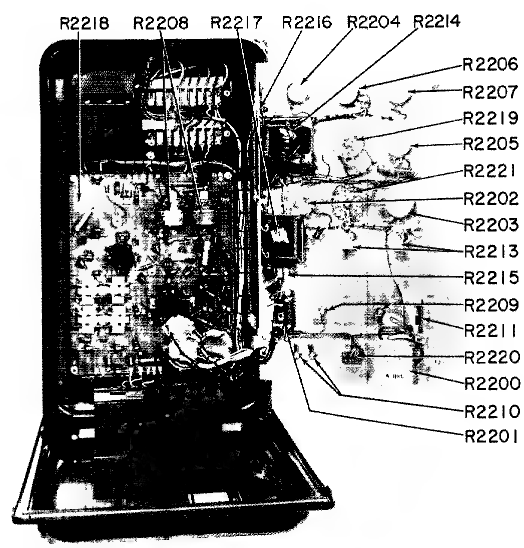

Fig. 27. Control panel, rear view

FIG. NO.	REF. NO.	DESCRIPTION
	R2200	Operation counter
	R2201	Control power circuit breaker
	R2202	Control selector switch with knob
	R2203	Test rheostat
	R2204	Time delay rheostat
	R2205	Resistance rheostat
	R2206	Bandwidth rheostat
	R2207	Voltage-level rheostat
	R2208	Relays
	R2209	Output test terminals
	R2210	External power supply terminals
	R2211	Reset switch
	R2212	Neutral light
	R2213	High and low lights
	R2214	Line-drop compensator reactor
	R2215	Thyrector
	R2216	Resistor
	R2217	Input transformer
	R2218	Component board
	R2219	Reactance switches
	R2220	External power supply switch
	R2221	Polarity switch

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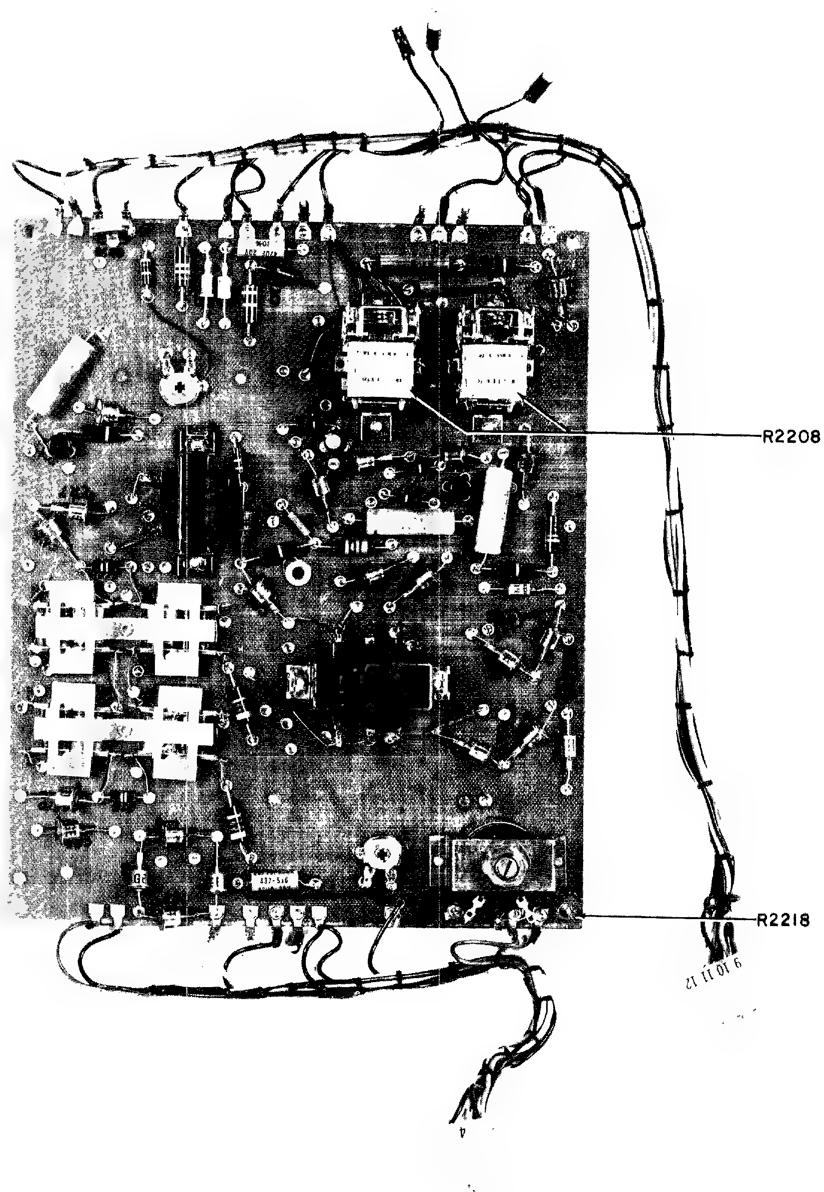

Fig. 28. Component board

NOTES

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VOLTAGE REGULATOR BUSINESS SECTION

GENERAL ELECTRIC

PITTSFIELD, MASSACHUSETTS

4-67 (3M)

PRINTED IN U.S.A.

26 APR 1967

Chief, Procurement Division, OL

25X1A ATTN : [redacted]

Chief, Real Estate & Construction Division, OL

Requisition No. 770-67-26291 [redacted] Electrical Distribution System) 25X1A

1. Please amend Requisition No. 770-67-26291, Voucher No. 67-9043, as follows:

a. Cancel Item 1 of the basic requirements.

b. Cancel amendment No. 1.

c. Add the following:

3 each General Electric ML-32 single phase, step-voltage regulators, rated 288 KVA, 14.4 KV with tap for reduced voltage operation at 13.8 KV at 200 amps, GE Cat. No. 29D 1843. Unit price $5,051.00. Regulators are to be operated in Delta.

2. In order for the Station to construct a building to house these regulators, it is requested that dimensional drawings, schematic diagrams and operational manuals be obtained and forwarded to this office as soon as possible. Also please try to obtain the best possible delivery date as the field has an urgent requirement for this item.

[redacted] 25X1A

Distribution:
Orig. & 1 - Addressee
1 - OL/RECD Project
1 - OL/RECD/UEB Chrono

25X1A OL RECD/UEB/[redacted]ded
(26 April 1967)

Rm

pmK